...artment of Agriculture Agricultural Research Service June 1990

Agricultural Research

Researching Wheat
...a Crop in Transition

Researching the Staff of Life

Orville A. Vogel is world renowned for his pioneering research that led to the first commercial semidwarf wheat for North America. He retired from ARS in 1973, but remains active today with the Vogel Wheat Research Fund that he and his wife Bertha founded in 1980. In this interview with *Agricultural Research,* he comments on the past, present, and future of wheat research, as an introduction to our series on "the staff of life".

Ag. Res. *How has wheat changed over the ages?*

Vogel. The distant forebears of wheat had little resemblance to today's plant. The seeds were not sources of food. They were paper-thin and dropped off onto the soil surface where they germinated and became the next season's crop. Being so light, they probably escaped full attention of insects, birds, and other animals.

Today's wheat thrives worldwide in a multitude of soil and climatic conditions and has heavy seeds that pack lots of nutrition. This has enabled humans to migrate onto the great expanses of land beyond the continuously warm areas of the Earth. But somewhere along the line, wheat changed from a self-seeding plant to one that needs human nurturing.

Ag. Res. *How has research contributed to the value of wheat as a food and feed?*

Vogel. Thanks to research, this food crop can be grown in many more areas of the world than was possible 50 years ago. Perhaps the most important contribution has been development of chemical weed controls. Other accomplishments are the development of high yielding semi-dwarf wheats for areas worldwide; increased economical uses of fertilizers, herbicides, fungicides, and seed and seedling protectants; and more efficient farm machinery.

Ag. Res. *What are our major challenges today and what research projects will be most important in the next decade?*

Vogel. Research challenges include finding ways to better control erosion and keeping plants healthy. We need to strengthen research on soil microbiological constraints to controlling erosion through the use of crop residues. And we must improve Integrated Pest Management research to benefit a wider range of general and localized systems of crop management. Another related challenge will be to attract talented young scientists to our research programs. We must show them they can have a rewarding future.

Ag. Res. *What do you tell people who object to spending more research money on wheat, a surplus crop?*

Vogel. It's questions like this that get my hackles up. It's because of solid research progress that we have a stable wheat production and even a surplus. Wheat surplus, like any other surplus product in industry, results from actual or anticipated profits which are influenced mainly by price supports and political regulations. Of course, scientists can't control economic and political variables, but we can keep ahead of diseases that constantly mutate and migrating insects that can devour entire fields.

Once research has been closed out for external reasons such as the one you mention—surpluses—the project is mothballed and the researchers may be dispersed. When economic conditions change, our research priorities will be reordered—but we may not be able to assemble a new team and solve major problems fast enough. We need to be continuously at work, and we need highly trained research personnel at our major public and private experiment stations. The public can ill afford to vacillate in its support for research designed to maintain affordable production.

Ag. Res. *What future role do you envision for the new biotechnologies, such as genetic engineering and other state-of-the-art sciences, in wheat research?*

Vogel. These types of science will be very, very important. Compared to field studies, we can get more reliable findings and faster use of these high-tech approaches in carefully controlled laboratory environments. Recent advances through the use of genetic engineering have been mind-boggling. Plant improvements in the future will occur even faster because of these new sciences and approaches to solving problems.

Ag. Res. *What role will biological control play?*

Vogel. This is a wide open area that needs exploration. Good fungi attacking bad fungi; good bacteria fighting bad bacteria; and beneficial insects eating crop-destroying insects. I expect great advances. Just as we have seen the pharmaceutical industry adapt microbes from the soil to work as human antibiotics, we should see researchers developing microbes to fight soil diseases and insects.

Ag. Res. *What changes do you predict in the future?*

Vogel. I predict increased competition for research funds. There is never enough money to adequately support all demands. There will be a big challenge in allocating public resources.—Interview by **Dennis Senft,** ARS.

U.S. Department of Agriculture Agricultural Research Service June 1990

Agricultural Research

Dear Readers:

We goofed. Our mistake, in the June issue of *Agricultural Research*, is in the legend of the wheat class map on page 8.

We inadvertantly transposed the symbols that represent soft red winter wheat and durum wheat. The corrected legend, shown with the map at right, shows the symbol ▼ for durum and ◆ for soft red winter wheat.

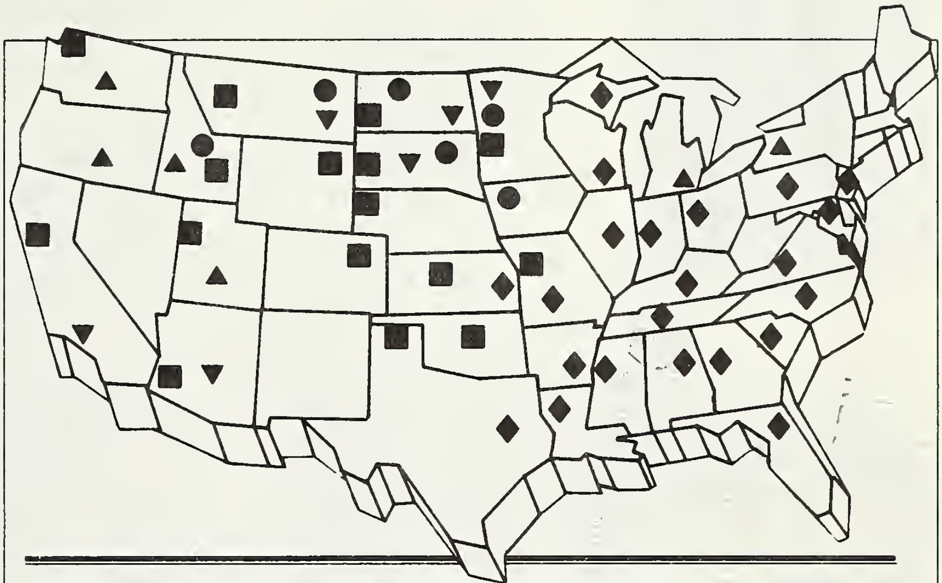
Most of the country's durum is grown in North Dakota. The state's 66 million bushels accounted for 72 percent of the 92 million bushels of durum produced in 1989.

In the same year, five Midwest states grew two-thirds of the total 548 million bushels of soft red winter wheat. Those states are Illinois (105 million bushels), Missouri (87 million bushels), Ohio (63 million bushels), Arkansas (53 million bushels), and Indiana (52 million bushels).

If you received multiple copies of the June issue for your own distribution, you can help us advise readers by passing along this notice.

Remember, part 2 of our 3-part series on wheat will appear in July, and part 3 will be in August.

The Editors



CLASSES OF WHEAT—WHERE THEY GROW

Farmers in the United States grow either winter or spring varieties of wheat, in five main classes. Winter wheat is sown in the fall, harvested in summer. Spring varieties are planted in spring for summer to early fall harvest.

■ **Hard red winter.**—Most U.S. wheat is of this class, and it is important in breads (35 percent of estimated 1989 production).

● **Hard red spring.**—Another important bread wheat, its high protein and strong gluten improve baking quality of hard red winter wheat. Subclasses: dark northern spring, northern spring, red spring (21 percent)

◆ **Soft red winter.**—High yielding. Cakes, pastries, quick breads, crackers, cookies, snack foods (27 percent).

▲ **White.**—Major export wheat for the Far East, especially white club wheat used in noodles. Used to replace hard red winter wheat in bakery products, breads, and noodles. Subclasses: hard white, soft white, western white, and white club (12 percent).

▼ **Durum.**—Hardest U.S. wheat. Spaghetti, macaroni, other pasta products. Subclasses: hard amber durum, amber durum, durum (5 percent).

U.S. Department of Agriculture
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Agricultural Research

IN THIS ISSUE: More than 90 scientists and other authorities were interviewed by a dozen ARS Current Information Branch writers for the articles in the three-part series starting this month on the crop known for centuries as the staff of life.

Part 1, in this month's issue, focuses on research on the wheat plant, including its genetic ancestry and the qualities we seek to use to human advantage. Also covered are some possible new uses for the wheat kernel as a commodity of commerce.

Cover: Breakfast, lunch, dinner, and snacks almost always include foods made from hearty wheat. (K-3607-20)
Photo by Keith Weller.

Next month, in Part 2, we will look at how wheat farmers can utilize new tools and new technologies to fight the seasonal struggle for a bountiful harvest against the historical ravages of weather, pests, and disease.

Part 3, in the August issue, will examine how wheat proteins and genetics guide the search for a better wheat product, and how new strategies for protecting the harvest will speed its success in the global marketplace.

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Wheat

A Crop in Transition

Ripening wheat on the Palouse hills of Washington. Photo by Doug Wilson. (K-1443-2) Inset: Geneticist David Porter (left) and entomologist Jim Webster examine wheat seedlings infested with Russian wheat aphids. (K-3624-1) Photo by David Nance

Just about now, it's beginning. Down South, in Georgia, Florida, and Texas, the rich soil gives up the year's first fat kernels to the whirling blades of the combines. They will continue, scarcely pausing, the harvest sweeping north into summer twilight until the last stalks are stripped of their bounty in Montana and the Dakotas.

Soon after that, next year's crop will green the vast plains edging the Rockies and the steep hills of the Palouse.

Although the cycle of wheat production seems eternal, man continues to change and adapt this venerable crop. Where is it headed? This issue of *Agricultural Research* begins a three-part series to sketch some of the directions it may travel.

How will this plain-looking grass, the seed of civilizations past, shape future economies in the United States and the world?

The wheat berry, milled into flour, is far and away—and increasingly—the primary food grain consumed by Americans. According to the latest estimates, from 1989's 2-billion-bushel crop, we will eat 750 million bushels—about 3 bushels per person. Another 265 million bushels will go for domestic livestock feed and for seed.

Export projections call for 1.3 billion bushels. For perspective, consider that we grew only about one-tenth of the world's wheat last year. But U.S. farmers grew 37 percent of the wheat exported worldwide.

In recent years, though, U.S. exports have faced tougher competition from other wheat-exporting countries. That calls for better decisions on what to grow and on how to grow and sell it.

The first word in war is spoken by guns. But the last word has always been spoken by bread.

Herbert Hoover, 1943

Researchers are working to boost the odds that those decisions will pay off.

Political and economic change in Eastern Europe, the Soviet Union, China, and elsewhere may greatly alter traditional trade relationships. But will that mean new markets for U.S. wheat?

Wheat varieties developed in the United States brought the first 200-bushel-per-acre wheat yields to U.S. farmers and spurred the worldwide Green Revolution in the 1960's.

But these cornerstones of wheat breeding now have to support more weight: needs for wheat to resist the continual arrival of new pest and disease strains, to use less fertilizer, to require less water, to stand up to drought and other climate extremes, to meet demands for flour geared for specific—in some cases new—food uses, and to lower the amounts and environmental risks of pesticides.

It's all one big puzzle being put together today in 199 wheat research projects of the Agricultural Research Service. Many ARS wheat scientists collaborate with peers at universities. Testing their new strategies often means roles for wheat growers, food companies, and grain millers and bakers.

Computer Scrutinizes Wheat

Strategies to help millers could come from computers taking a new, close-up look at the wheat kernel itself.

Parts for airplanes, cars, and even the automatic teller machine at your bank were probably stress-tested by computer when they were still early in the design stage.

Now, this computer-assisted engineering may show wheat millers how to coax more flour from

JACK DYKINGA

Chemist Gregory Glenn analyzes a three-dimensional computer model of a wheat grain. (K-3604-1)

kernels, says Gregory M. Glenn of ARS at Albany, California. Currently, millers lose approximatly 8 percent of the potential flour yield from each kernel.

The research is a team effort of scientists at ARS, Washington State University, and Kansas State University.

Jeffrey A. Gwirtz at KSU explains that a mere 1-percent improvement in flour extracted from kernels could save $7 million annually for millers of soft wheats and $29 million at hard wheat mills.

The flour is wasted when the mill's rollers fail to cleanly separate the grain's bran layer from the endosperm, the flour-producing inner tissue. That endosperm, plus bran, may end up in feed bins for cattle instead of flour bins for bakers, according to Glenn, who works with the ARS Food Quality Research unit.

"We want rollers to fracture the grain closer to the bran-endosperm layer, instead of deep inside the endosperm," says Marvin J. Pitts at Washington State University, Pullman.

"In the same way a computer can show you where an airplane part is likely to fail, it can tell you where the grain is likely to crack," says Pitts. These simulations should "help millers fine tune the way they process wheat to better position the cracks, remove bran more cleanly, and rescue more flour."

The team should be able to experiment—at the computer terminal—with "dozens of milling tactics," he says. Structural Dynamics Research Corporation, Cincinnati, Ohio, developed the software.

The geometry of a wheat grain is so complex, says Pitts, that you can't do this analysis by hand. And it's a challenge even for a computer.

The Seed of Civilization

Despite the recent high-tech attention, wheat has had a say in civilization for thousands of years.

Bread has been one of the first words in the vocabularies of myth and history, of conquests, quarrels, civilization, and national growth.

In 1948, archaeologists from the University of Chicago dug through ruins in the ancient village of Jarmo in Iraq. Unexpectedly, they found kernels of wild and domestic wheat. The ruins, 6,700 years old, lay in the Fertile Crescent, the upper valley between the Tigris and Euphrates Rivers. The discovery was one of the first physical confirmations that wheat was cultivated by early civilizations. Art and myth hold this fact out to us in numerous ways.

Egyptian murals unearthed from tombs along the Nile lavishly depict the planting of wheat and its harvest by sickle. Ancient fables tell us it was the Egyptian goddess Isis who first spotted this life-sustaining grain waving alongside barley in the rich fields of Phoenicia. It was she as well who discovered how to mill flour and make bread, highly cherished by the ruling class.

Around the other side of the Mediterranean, Ceres, for whom cereal grains were named, was the Roman goddess of agriculture. While she, like her Greek counterpart Demeter, watched over the wheat fields, the Roman goddess Vesta reigned over the hearth. Vesta was often depicted holding a pan of bread, a main course at meals during the height of the Roman Empire.

"The early Romans depended heavily on wheat, but probably not for bread as we know it today," says Calvin R. Sperling, a botanist and

plant explorer with ARS in Beltsville, Maryland.

"Original forms of cultivated wheat had seeds tightly enclosed in hulls. Parching, pounding, or boiling was necessary to release the seeds. But this destroyed the gluten, which enables bread to rise, so the first use of wheat was probably for something like bulgur or an unleavened bread."

From Ancient Genes, Future Wheats

About 20 closely related species make up the "wild goat grass" genus to which wheat belongs. The name probably comes from the species' preference for "disturbed" soil such as that turned by the hooves of goats.

explains Sperling. The genus may have arisen in the Near East, although it can be found from western China to Ethiopia.

Sperling and other ARS researchers collect wild and primitive forms of wheat from all corners of its range so breeders and researchers can tap into this age-old, yet continually self-renewing, genetic reservoir.

On one trip to southeast Turkey, Sperling found a wild wheat growing in stands so extensive they looked like someone was farming them.

He has been particularly interested in collecting archaic wheats still grown in Turkey before they are lost forever. "Those wheats may look scrawny," he says, "but until you check them, you never know what traits they may have.

"For example, veteran plant explorer Jack Harlan collected a wheat that became known as PI [Plant Introduction] 178383 from southeast Turkey. It proved to be an incredible source of multiple disease resistance, particularly to diseases that attack wheat in the Pacific Northwest.

Almost all wheat varieties grown today in that part of the country have some disease resistance from that introduction."

Many archaic wheats are diploids, meaning they have two sets of chromosomes. Modern wheat, a hexaploid, has six sets. It is probably a result of a diploid wheat progenitor naturally hybridized with a tetraploid (four sets of chromosomes) wheat, according to Sperling.

"Since the diploids and tetraploids are direct ancestors to modern wheat, we are particularly interested in collecting them as sources of improvement," he says.

Tetraploid wheats found in northern Israel, Iran, Iraq, and Turkey are considered possible sources of genes to produce higher protein levels in modern wheat.

Wheat Emigrates to America

Wheat began shaping the Americas when Spaniards brought it to the New World in the 1500's.

In the American colonies, settlers planted it as early as 1602 on Cuttyhunk Island, near Martha's Vineyard.

Some 130 years later, the colonies of New York, Pennsylvania, New Jersey, and Delaware so heavily

A field of wheat in southeastern Turkey. Use of draft animals and hand labor allows farmers to cultivate wheat among the oak trees without cutting them down. Photo courtesy of Calvin Sperling.

shipped wheat, flour, and bread to points north and south that they were tagged the "bread colonies."

Wheat played a significant role in the nation's westward expansion. Even the Civil War, it is said, was in part a victory of bread over cotton.

During both world wars, wheat shipped from the United States and Canada made its way to Allied forces on the front lines. During the years following World War II, bread from wheat grown in North America again had the last word—nourishing European populations weakened by years of conflict and underdeveloped countries gripped by hunger.

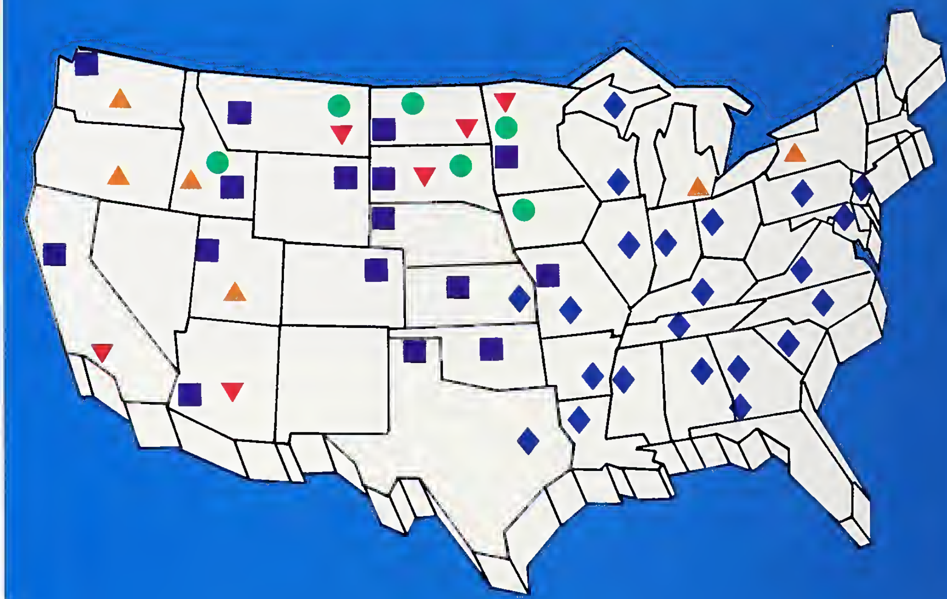
No one knew it, but in the waning shadow of that war, the groundwork was laid for a global revolution in food production.

Wheat Genes in Reserve

In 1946, ARS agronomist S. Cecil Salmon was assigned to Gen. Douglas MacArthur's Japan headquarters. Salmon's job—helping assess Japan's war-tattered farm economy—was immense. But he couldn't help noticing an agronomic curiosity—short, stiff-strawed, heavy-headed wheat plants. Salmon sent 16 strains of these plants to ARS' World Collection of Small Grains in Beltsville, Maryland.

Within a year, breeders working with the new strains included an ARS-Washington State University team in Pullman, Washington. Over the next 13 years, the team, led by ARS plant breeder Orville Vogel (see *Forum*, p. 2), produced numerous hybrid crosses and selections, which they shared with many other researchers.

Norman E. Borlaug used these wheat lines, including one that would be released by the Pullman team in 1961 as Gaines, in further breeding at the International Maize



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MICHAEL LICHTER

Agronomist Jack Morgan (left) and plant research technician Barry Weaver measure gas exchange in wheat plants at the ARS Great Plains Systems Research Unit at Fort Collins, Colorado. (K-3599-15)

and Wheat Research Centre in Mexico. His work breeding and distributing wheat for Mexico, Pakistan, India, Turkey, and Afghanistan would win a Nobel Prize for Peace in 1970.

Today, three decades after Gaines and other semidwarf wheats sparked the Green Revolution, wheat continues to be a vital link to peace and development, helping countries often threatened by starvation grow into modern, self-sufficient, and, in some cases, food-exporting nations.

But plant explorers today continue to gather wheat plants and seeds. They do this because breeders in the United States and all over the world need access to the widest possible genetic diversity to find the best wheats for tomorrow's farms, mills, and dinner tables.

The objects of their search: varieties with new or improved traits for qualities such as disease and insect resistance; tolerance to drought, saline soils, and other environmental conditions; improved milling and baking qualities; and higher nutrition.

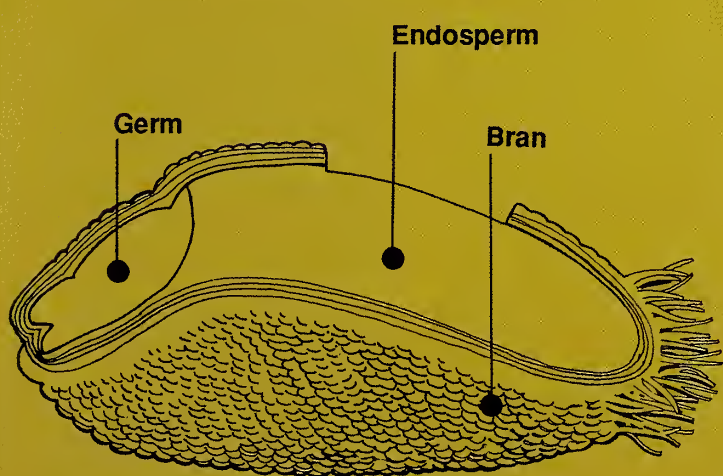
The raw material for these improvements lies in the remarkable genetic variation within plant species. For example, scientists at the ARS Great Plains Systems Research unit, Fort Collins, Colorado, recently found much variation in water use efficiency and photosynthetic efficiency among wheat lines.

"Such variation suggests that it may be possible to genetically select and thus improve these characteristics in future varieties," says Jack A. Morgan, agronomist at Fort Collins.

The country's main genetic "library" of wheat is in Aberdeen, Idaho, at the ARS National Small Grains Collection. This collection, moved from Beltsville in 1988, holds more than 110,000 accessions of some 130 species and subspecies of wheat, barley, rye, rice, oat, and triticale and related wild species. Forty percent—43,000—of the accessions are wheat.

While breeders and researchers worldwide draw upon the accessions, ARS scientists at the National Small

PARTS OF THE WHEAT KERNEL—



Bran—The kernel's fibrous covering. Removed in milling except in whole wheat flour, bran contains much of wheat's B vitamins and trace minerals.

Germ—The seed's embryo, which sprouts to form a new plant. The germ contains nearly all of wheat's oils—and these are high in polyunsaturates. Retained for whole wheat flour, the germ is milled out of white flour to prevent rancidity. Germ is high in B vitamins and trace minerals.

Endosperm—The core of the kernel. Endosperm is ground up to make white flour and holds most of wheat's protein, carbohydrates, and iron, as well as some B-complex vitamins.

MICHAEL LICHTER

Grains Germplasm Research Facility in Aberdeen continuously acquire, maintain, evaluate, and enhance these genetic archives.

"Wheat accounted for over 50 percent of the more than 98,000 accessions distributed worldwide from our collection in 1989," says agronomist Darrell M. Wesenberg, research leader at the facility. Backup seed supplies for Aberdeen are kept in Fort Collins at the ARS National Seed Storage Laboratory, where scientists also work to extend the seed's storage life.

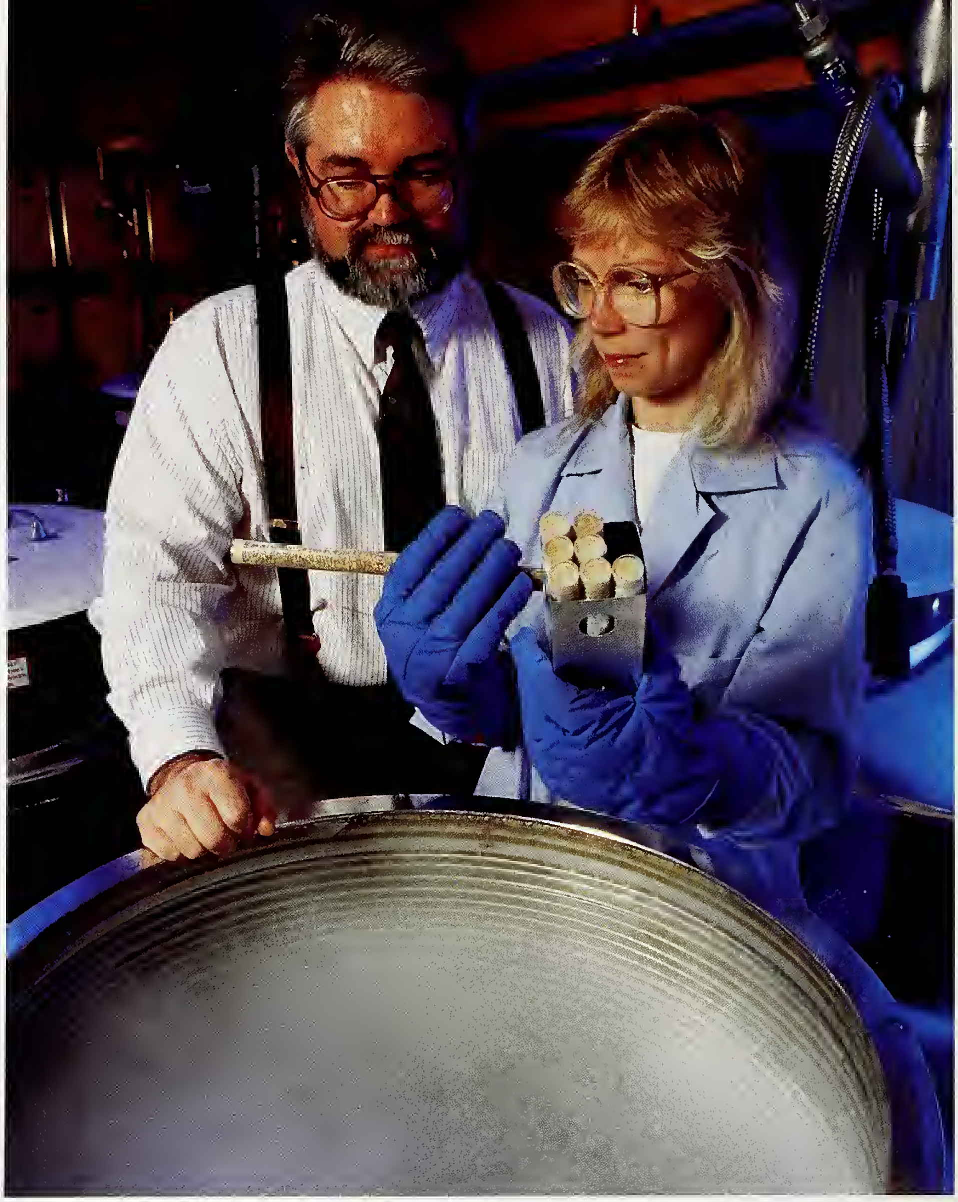
"Currently, some 600 wheat samples are frozen in liquid nitrogen at minus 320°F," says Fort Collins geneticist and laboratory director Steve A. Eberhart. "This may preserve seeds up to 100 years or more and at lower cost compared to traditional storage in temperature-controlled rooms."

Sometimes it's by accident that Aberdeen's germplasm eases the hunger for better wheat. In the withering drought of 1988, technician Barry A. Weaver at the Great Plains Systems Research unit was checking plants being evaluated for drought tolerance. Instead, Weaver found a wheat line from the USSR that seemed to resist the Russian wheat aphids attacking the experimental plots.

This insect has cost U.S. growers of wheat and other small grains more than $240 million since the tiny marauder was first spotted in Texas, about 500 miles southeast of the Fort Collins lab in 1986.

Plant breeders in the Great Plains are now using aphid resistance from the USSR wheat at Fort Collins for future commercial varieties.

Systematically tracking down aphid resistance is the task at Stillwater, Oklahoma. So far, scientists there have screened about one-fourth of the Aberdeen collections.



Agronomist Phillip Stanwood and laboratory technician Vicki Hernandez examine vials containing wheat seeds that are about to be frozen in liquid nitrogen. (K-3597-6)

"We have found good resistance in common wheats. We're also exploring the possibility that wheat's relatives and ancestors might have aphid resistance that we could breed into wheat. One of the more promising relatives is *Triticum tauschii*," says ARS entomologist Robert L. Burton, director of the Plant Science Research Laboratory.

The Stillwater team wants faster ways to expose useful qualities for further study. That's why they are hunting down a biochemical marker that signals insect resistance. This would speed preliminary screening: Scientists wouldn't have to expose plants to aphids to get a first-cut check for resistance.

While the Russian wheat aphid is a new pest in the United States, researchers continue to give wheat stronger resistance to old pests that can show up in new forms. An example is septoria, a fungal disease that costs millions of dollars in crop losses every year. Some wheat growers lose their entire crop to it.

But in the past few years, researchers at the ARS Cereal Crop Improvement Unit, Bozeman, Montana, bred and released more than 20 septoria-resistant lines. These lines today fuel the breeding of new commercial varieties in 10 states and 11 foreign countries.

Two New Protein Champs

Two of the newest varieties of semidwarf hard red spring wheat sprouted from cooperative work by ARS and the Minnesota Agricultural Experiment Station. And when it comes to protein, their kernels are at the head of the class.

One of the new wheats, Vance, yields at least as well as Marshall, the most popular variety in Minnesota. It also has half a percentage point more protein.

"That boost in protein without a sacrifice in yield may often put some extra money in growers' pockets," says ARS agronomist Robert H. Busch at St. Paul.

Most years, he explains, millers pay premium prices for high-protein hard red spring wheat. They blend and mill it with lower protein wheats. Result? A flour that mixes up into bread dough of the required strength.

Protein of the other new variety, Minnpro, averaged 1.8 percentage points higher than Marshall in sev-

At the ARS Wheat and Other Cereal Crops Research Laboratory in Stillwater, Oklahoma, two wheat plants (standing) show possibility of resistance to Russian wheat aphids. (K-3624-6)

MICHAEL LICHTER

(K-3579-19)

A Nutritional Bonanza

Nutritional content of wheat depends on the variety, climate, and other factors. Figures are averages per 100 grams (about 3.5 ounces) of whole wheat flour unless stated otherwise.

Protein: Wheat contains more protein than rice or corn. Whole wheat flour averages 13.7 grams protein per hundred grams (g/100 g).

Complex carbohydrates: Unlike simple sugars that blood takes up rapidly, complex carbohydrates give a steady supply of energy. Carbohydrates in whole wheat flour average 72.6 g/100 g.

Fiber: This undigestible carbohydrate benefits the intestinal tract. It, along with other complex carbohydrates and fiber-containing foods in the total diet, helps cut risks of colon cancer and heart disease and enables better control of diabetes. Flour, 2.1 g/100 g; bran, 7.2 g/100 g.

Fat: Wheat itself—except the germ—has almost no fat (1.9 g/100 g), although nearly all foods made with wheat have fat added. The fats in wheat germ oil are 64 percent polyunsaturated and high in linoleic acids. These acids are precursors of prostaglandins, which help the body regulate hormones.

Vitamins and minerals: *Thiamine* (0.45 milligram per 100 grams), an essential B vitamin, promotes appetite and healthy nerves and helps metabolize fats and carbohydrates. Two other B vitamins in wheat are *niacin* (6.4 mg/100g), which helps the body use protein efficiently, and *riboflavin* (0.2 mg/100g), which promotes growth and use of carbohydrates, fat, and protein. The mineral *iron* (3.9 mg/100g) combines with protein to form blood hemoglobin; *zinc* (2.9 mg/100g) helps skin heal and grow.

Among the trace minerals in wheat, *selenium* helps protect cell membranes, and *magnesium* and *potassium* aid the heart and cardiovascular system.

TIM MC CABE

In his Albany, California greenhouse, ARS chemist Frank Greene checks developmental state of wheat used in grain protein studies. (K-2629-10)

eral years of tests. That's a half point over Len, the previous record holder among semidwarf hard red spring wheats.

Minnpro yields about 10 percent more grain than Len but 7 percent less than Marshall.

Farmers will decide whether to grow Minnpro, Busch says, after weighing the prospective dollar value of its protein bonus against some lower protein varieties' higher yields.

Something for Every Appetite

When it comes to foods, we like wheat plain, we like it fancy. Mainly we like—lots of it.

In a year, Americans eat enough wheat flour to equal about 195 loaves of bread per person.

Our kitchens and bakeries serve up an vast array of breads—from hearty whole wheat to airy French and Italian whites and pungent San Francisco sourdoughs. And beside dozens of types of sandwich breads and rolls are a legion of their increasingly popular cousins from other cultures: bagels, croissants, pitas, couscous, won-tons, tortillas. Not to mention that favorite "Italian" specialty, pizza.

For dessert and snacktime, we also find cakes, doughnuts, cookies, crackers, and biscuits. Pie, without its flour crust, would only be so much baked fruit or pudding.

For breakfast, supermarket aisles beckon and bewilder with a changing galaxy of cereals from wheat and other grains.

Some part of the wheat berry also goes to make gravies, pudding, soup, and sauces—even some soy sauces.

There's wheat literally all around the home, if you know where to look. Your vitamin shelf may hold capsules of iron, thiamine, and riboflavin extracted from wheat bran, though cheaper synthetics control the mass vitamin market.

In the bathroom you may find shampoo containing wheat germ oil and cosmetic powders that are made with flour.

A small proportion of the wheat crop also shows up in unsuspected—but everyday—places, chiefly in adhesives. The kindergartener's artwork hanging on the refrigerator may have been assembled with flour paste. The wooden table and chairs in the dining room may be held together with wheat-based glue. And while you're hanging wallpaper, that goo oozing down the wall may be chiefly flour and water.

Some of today's most common building materials—plywood and drywall—make use of wheat glues.

In fact, the word glue loaned its name to gluten, "a smear of different water-insoluble protein shapes and types" in wheat and other plants, says Arthur Morgan, a chemical engineer who is ARS national program leader for exports. Flour adhesives once dominated the industry, but Morgan says their conquest by synthetics is one more sign that "the future of new wheat products is predominantly in foods rather than industrial goods."

Wheat Foods by the Numbers

Statistics on wheat consumption point to changes in what people are buying more of and where they are buying it.

Per capita consumption of wheat by Americans grew from 117 pounds in 1980 to 128 pounds in 1987, something the USDA Economic Research Service in a December 1989 report calls "one of the first reversals in flour consumption in the developed world."

But despite the expanding market, wholesale bakeries face stiffer competition right inside their traditional sales outlets—supermarkets and other grocery stores. The number of in-store bakeries leaped 37 percent between 1982 and 1987—from 13,800 to 18,850.

(continued page 14)

Seventy Years of Wheat Breeding

Of all ARS efforts to breed better wheat, one of the oldest and most productive is the ARS-Purdue University Small Grain Improvement Program, which began in 1921 in West Lafayette, Indiana.

The program really began producing significant results and new varieties shortly after World War II.

"It takes a long time to establish approaches to breeding new varieties," says agronomist Marvin M. Schreiber, who supervises the program. "But once you get going, results often multiply."

RICHARD NOWITZ

Sally Mackenzie, assistant professor of agronomy at Purdue University, evaluates an agarose electrophoretic gel containing wheat genomic DNA and cloned DNA of wheat. The clone is used to uncover relationships between cultivated wheat and its wild relatives. (K-3591-3)

In recent years, varieties produced by the program account for more than 70 percent of the 15 million acres of soft red winter wheat in the eastern United States.

"You could completely pave Massachusetts with soda crackers baked from flour made from what's grown in these varieties each year," says John J. Roberts, an ARS plant pathologist who is a cooperator in the program.

RICHARD NOWITZ

Entomologist Richard Shukle reads a gel map of wheat DNA samples. (K-3584-10)

Roberts, based in Griffin, Georgia, at the ARS Regional Plant Introduction Station, recently conducted a study to see what the Purdue/ARS program's 25 varieties have meant to the farmer. For starters, he says, they've meant more than 7.8 billion bushels of soft red winter wheat, generating over $20 billion in farm income.

"Our improved varieties," he adds, "have meant over $5 billion in increased income to farmers compared to cultivars they replaced."

To chart the increases, he compared the Purdue/ARS varieties to Trumbull, which was a standard from about 1916 until the mid-1930's. Among the yield breakthroughs was Arthur, released in 1968. "It yields about 82 bushels an acre compared to 42 for Trumbull under current management practices," Roberts says.

The program's premiere variety—released in 1946—was Vigo, one of the first red winter wheats that could stand up to U.S. wheat's worst disease, leaf rust. Vigo was followed by Knox in 1953 and Dual in 1955. But, Roberts points out, leaf rust fungi mutate and overcome existing resistance in 5 to 10 years, so new varieties are always in demand.

"Dual," he adds, "was also one of the first soft wheats with natural resistance to the Hessian fly, which last year caused $21 million in damage—just in Georgia—to nonresistant varieties."

The program originally focused on leaf rust but now embraces all major agronomic traits of wheat as well as milling and baking quality.

When the cereal leaf beetle invaded the United States in 1963, West Lafayette responded with Downy. "That variety's leaf hairs are now arousing interest as a possible new way of resisting leaf rust as well," Roberts says.

Another wheat fungus being targeted is *Septoria tritici* leaf blotch. ARS and Purdue countered with Oasis. "The variety got its name because fields of it stood out like green oases when leaf blotch had killed off all the wheat plots around it," Roberts says.

One specialty variety, Redcoat, was originally introduced in 1960 for its excellent stiff straw and stem rust resistance. Still grown in Pennsylvania after 30 years—exceptionally long for a wheat variety—it's easy to recognize even when it's reached the grocery store.

"The flour made from Redcoat is used specifically to make Twinkies," Roberts explains.—By **J. Kim Kaplan,** ARS.

Milestones and Millstones

1780: James Watt designs steam-powered mill. By 1870, steam powers more than one-fourth of the 22,000 U.S. mills.

1819: Jethro Wood patents cast iron plow to replace traditional wooden plow.

1831: Cyrus Hall McCormick invents and publicly tests his revolutionary new reaper in Virginia. The two-wheeled, horse-drawn reaper was one of the first steps to farm mechanization.

1836: First combined harvester-thresher, drawn by horse, patented by H. Moore and J. Hascall of Michigan. The self-propelled combine appeared in 1908.

1837: Steel plow invented by Illinois blacksmith John Deere, widely replacing the cast iron plow and cutting by one-third the animal power needed to turn the soil.

1874: Turkey Red, a hard red winter wheat, brought to Kansas by Mennonites from the Crimea. The first highly successful wheat in the United States, by 1919 this drought-resistant, winter-hardy variety represented 80 percent of Kansas wheat acreage and had spread to several other states.

1878: An all-roller mill constructed in Philadelphia leads the way to more efficient, cheaper, cleaner milling.

1892: Canadian Marquis developed as the first successful cross-bred spring wheat. Bred from wheats from India and Poland, it established a quality standard for spring wheat. By 1919, U.S. farmers planted it on 11.8 million acres, helping supply Allied forces in World War I.

1923: E.C. Stakman publishes the theory that rust spores become airborne and migrate from southern areas to infect wheat in the north.

1926: Hope wheat introduced. A cross with Marquis, it resisted leaf and stem rust, bunt, and loose smut.

1934: University of Minnesota releases Thatcher, another cross with Marquis. Thatcher carried some rust resistance and was a top-quality milling and baking variety.

1961: Gaines, the first semidwarf soft white winter wheat grown on large acreage, released by ARS and Washington State University. It becomes one of the highest yielding wheats.

1967: North Carolina State University releases Blueboy, first semidwarf soft red winter wheat variety and first wheat variety to yield more than 100 bushels per acre east of the Rocky Mountains.

1975: Cando, the first semidwarf durum variety, is developed.

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Wheat harvest in Kansas

A Bureau of Labor Statistics survey found, meanwhile, that shoppers are more frequently bypassing white bread—the staple of the wholesale industry. While total consumer spending for baked goods rose 20 percent from 1980 to 1984, the survey said larger increases went to certain baking products, topped by a 43-percent jump in spending on cookies, and 36 percent more for breads other than white.

"The demand for instantness fuels these trend shifts, and potential new wheat products could prosper by meeting this demand," says Morgan.

Hence the surge, for example, in Oriental noodle soup mixes that are spoon-ready after a few minutes of simmering. Nearly all these mixes are imports, though often containing American wheat.

Coupled with instantness, people want freshness. Morgan says time-

hungry shoppers might flock to the freezer section for bread dough they could thaw, form into any shape, and "bake" fresh in the microwave. The biggest hurdles: getting the dough to rise properly and giving the loaf a crisp, brown crust.

Dough rises when bread yeast blows bubbles of carbon dioxide "like champagne coming out of a bottle," Morgan says. "But yeasts don't like to be frozen, so instead you'd need a substitute—a chemical compound to release carbon dioxide, or some way to inject it directly. Or you'd need a genetically altered yeast that could handle freezing and thawing."

An even trickier problem might be getting a microwave to perform the alchemy of crust formation. That's a combination of drying—created by heat—and browning from the dough's sugars and acids. "One might be able to coat the frozen dough with certain sugars and acids to get a good crust in the microwave," says Morgan.

You may not see microwave bread in stores soon, but consumer demands for speed, freshness, and diversity explain why bakeries are flourishing in supermarkets. Industrial bakeries, with their longer, slower distribution chains, are playing catch-up by expanding their product lines.

Large-scale bread baking—aside from its technology for high volume and speed— "still basically mimics the environment of the old-fashioned brick oven," Morgan says. "We need ways to put more value in wheat—such as more diversity and nutrition—instead of just replicating the brick oven on a grand scale."

For example, a more nutritious "rice" made from wheat came from

Plastic From Wheat?

Tomorrow's sandwich bread might come wrapped in a bag that's made from wheat.

As a notable exception to the focus on food uses, ARS researchers have begun seeing whether some unique qualities of wheat starch could give the crop a new market niche—biodegradable plastic.

It's starch that makes such plastics biodegradable: microorganisms eat it. But the starch in plastics now marketed is largely from corn and typically makes up only 6 to 7 percent of the products. Plus, corn's starch granules are relatively large, about 15 microns on average. This limits the thinness of the plastic film because it creates weak spots in the plastic.

Wheat starch granules come in two fairly distinct sizes, and the smaller granules, averaging 6 microns, are much thinner than corn's. Researchers say finding an economical way to isolate the small granules could be a first step toward thinner, starchier plastic films that would be stronger yet more biodegradable.

At the Northern Regional Research Center, Peoria, Illinois, chemist Jerold A. Bietz is coordinating studies aimed at sorting wheat starch granules by their size. The trick: using airstreams of differing velocities.

Meanwhile, at the Southern Regional Research Center in New Orleans, chemical engineer Robert J. Hron, Sr., plans to test whether a different process—using a liquid cyclone—is feasible. A slurry of starch and hexane is pumped into a metal cone at an angle so the slurry spins as if it were in a centrifuge. Heavier starch particles exit the cone's narrow, lower end.

Impetus for this research and other projects comes from the National Wheat Growers Foundation, which asked a technical committee of industry, government, academic, and grower representatives to suggest research leading to expanded uses of wheat.—By **Ben Hardin,** ARS.

Food technologist Den-Shun Huang neatly solved a complaint of Chinese bakers—"Flour from some California hard red wheats made dough too sticky."

research Morgan did as an ARS chemist in the 1970's.

He cooked up a way to peel off wheat bran's outer layers, leaving intact the aleurone— the white, innermost layer of bran. Peeled wheat looks and cooks like rice but is more nutritious, he says.

Morgan, who holds several patents from his research with wheat and other foods, says the process "will work on any grain. You warm the grain, douse it with an alkali and spin it in a hydroclone." Peeled grain comes out the bottom of this machine, and bran comes out the top.

American Wheats for Asian Delicacies

In baking laboratories at Albany, California, scientists turn out tender, moist, Chinese-style steam bread and delicious Chinese noodles with flour from California wheats. They're seeing how well those flours measure up in foods popular in China and other Pacific Rim countries.

In one test, food technologist Den-Shun Huang, formerly at the Albany laboratory, neatly solved a complaint of Chinese bakers: they said flour from some California hard red wheats made dough too sticky. The ideal dough is as smooth as a baby's skin.

The solution was to blend two California wheats—ordinary hard red wheat plus low-protein batches of a recently developed hard white variety, Klasic. Steam breads made from the blended flour boast the smooth, glossy-white finish and consistency bakers prize, says ARS food technologist Maura L. Bean, who worked with Huang.

The blend yields good Chinese-style noodles as well. The California Wheat Commission, sponsor of the experiments, now markets the wheats for export as a special "California Blend."

At ARS' Western Wheat Quality Laboratory at Pullman, Washington, food technologist and head baker Herbert C. Jeffers and coworkers prepare and rigorously test batches of a sweet treat, spongecake, favored by Japanese and Koreans for special occasions. Bakers in those countries rely almost exclusively on the Pacific Northwest's soft white wheats for this delicacy. So Jeffers and crew test flours from experimental wheat varieties to make sure West Coast growers get only those wheats that yield superb spongecake flour.

In Japan's noodle shops, bakers prefer Australian wheats to those from Oregon, Washington, or Idaho. Why? Aussie wheat's special advantage is its lower ratio of amylose to

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MICHAEL LICHTER

Research geneticist Harold Bockelman verifies wheat seed inventory held in cold storage at the National Small Grain Collection in Aberdeen, Idaho. The laboratory contains over 43,000 wheat accessions as well as over 110,000 accessions of various small grains (barley, oats, rye, triticale, and rice). (K-3623-11)

amylopectin, two starch components. That's according to experiments funded by the wheat commissions of the three states and performed by Pullman scientist Gordon L. Rubenthaler (now retired) of ARS, Washington State University colleagues, and Hiroshi Toyokawa (now at Chiba, Japan).

The lower ratio of amylose to amylopectin gives udon noodles a "good bite," a special chewiness that scientists call viscoelasticity. Armed with this clue, Pacific Northwest breeders might now be able to build a better noodle-quality wheat.

Snacks of the Future

New snacks and other convenience foods from wheat might be flavored or filled with tasty combinations of fruits or vegetables.

Engineer Richard H. Edwards at Albany, California, is running experiments aimed at cooking up such products for consumers in the United States and overseas.

His mechanical helper in all this is an extruder—a device that does for a food manufacturer what a food processor does for a gourmet cook.

"Extruders can mix, shear, knead, heat, cool, cook, concentrate, pasteurize, sterilize, shape, or form," says Edwards. They produce hundreds of foods, from cheese-coated puffs to breakfast flakes, stars, loops, and yes, even miniature bats, thanks to a recent movie about a black-caped crime-fighter.

Edwards, Robert Becker, Robert N. Sayre, and Albert P. Mossman of the Food Quality Research Unit agree that extruded foods might offer a way to get wheat products into export markets where sales of U.S. wheat and flour have sagged.

Using fresh, dried, or concentrated fruits or vegetables in these foods neatly sidesteps problems in exporting freshly harvested produce. Those hassles can include perishability, strict fumigation requirements, and import quotas.—ARS writers **Matt Bosisio, Jim De Quattro, Ben Hardin, J. Kim Kaplan, Dennis Senft,** and **Marcia Wood** contributed to this story.

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ACHOO!

Must Be the Roaches!

Pollen, grasses, mold: the three most commonly heard words as we hit allergy season.

But cockroaches?

That's right. More and more, scientists are realizing that the disgusting cockroach doesn't just threaten our mental health, but also our physical well-being.

Results from several studies by the National Institutes of Health, and several by allergists, indicate that 10-15 million people in the United States are allergic to cockroaches. Allergic people have a range of reactions, depending on their level of sensitivity. Mild reactions include rhinitis, or runny nose, and in some cases skin irritation. But in a very sensitive person, difficulty breathing—even death from shock—can result.

Exposure to cockroach allergens can mean a severe asthma attack for asthmatics with cockroach sensitivity. According to studies done by Bann Kang, M.D., Chief of Allergy and Clinical Immunology at the University of Kentucky, 61 percent of asthmatics show a sensitivity to cockroaches.

Other studies in Thailand and Taiwan produced similar results, indicating that the problem of roach allergy may span the globe.

For shellfish lovers, a cockroach allergy can be serious news. That's because cockroaches and certain shellfish such as shrimp, crabs, and lobster are arthropods (a category of organisms), and there is evidence that developing an allergy to one arthropod can predispose a person to become sensitive to another.

Among the evidence is the fact that serum from patients in Chicago who are allergic to German cockroaches also showed a reaction to the flying Asian cockroach, currently found only in Florida. That's according to studies by entomologist Richard J. Brenner, of the ARS Insects Affecting Man and Animals Research Laboratory in Gainesville, Florida, and immunologist Rick Helm, of the Department of Pediatrics at Children's Hospital in Little Rock, Arkansas, when he worked at the Mayo Clinic.

There's also anecdotal evidence. "We have had entomologists in the profession develop allergy to cockroaches and thereafter have an allergy to shellfish," Brenner says.

"This issue is even entering the legal realm," he says. He should know, being called as an expert witness in a Georgia lawsuit that was brought against a pest control company. The plaintiff, the widow of a 30-year-old man, alleged that the pest control company had caused her husband's death from pesticide poisoning.

What the evidence showed, Brenner says, was that the victim was an asthmatic with a known allergy to "house dust" and a major component of "house dust," —second only to house dust mites— is cockroach parts.

The victim had suffered a serious asthma attack 1 month before his death, and one attack often predisposes an asthmatic to a potentially fatal second attack unless under strict doctor's care.

The jury—and a higher court on appeal—pointed the finger at arthropod parts, not the pest control firm.

Below: In a typical scratch test, suspected allergens are inserted beneath the skin. (K-3579-6) Right: Later, telltale signs of an allergic reaction appear—a welt and redness. (K-3579-11)

RICHARD NOWITZ

Arthropod allergy presents a significant threat to human health. And it's a threat that is increasing.

"It is clear that this issue raises all kinds of questions for the future," Brenner says.

"People simply cannot continue to view cockroaches as just a nasty nuisance. Arthropod allergy presents a significant threat to human health."

And it's a threat that is increasing.

Some scientists believe that the steady increase in the incidence of allergy over the last 25 years has been partially the result of our drive to make our homes more airtight.

Brenner and medical anthropologist Kathleen Barnes, of the University of Florida, compared the quality of home construction with the incidence of allergy in the Dominican Republic, where the range of ventilation in homes is wide. Their conclusions: the more airtight and better-made the home, the greater the incidence of insect allergy.

Further supporting the hypothesis is the fact that people 30 and older have the most serious allergic reaction to insects due to chronic, long-term exposure, according to studies compiled by Judith Massicot and Sheldon Cohen, researchers in the Immunology, Allergic, and Immunologic Disease Program at the National Institutes of Health.

And the incidence among women, who, it could be argued, have traditionally spent more time in the home, is higher.

"Librarians in archives are at risk for cockroach allergies because of long-term exposure to a chronic accumulation of cockroach and other arthropod parts," Brenner says.

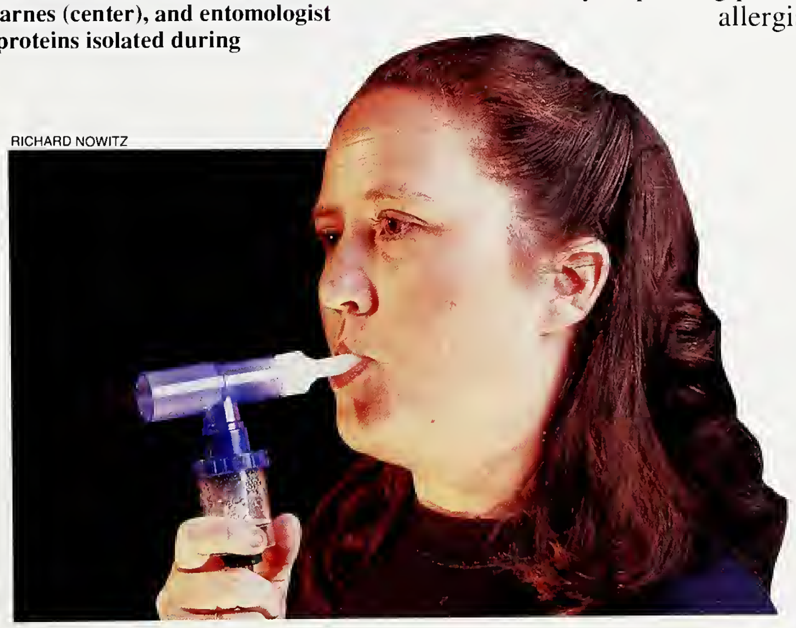
Brenner has assembled a team of scientists and doctors pooling their expertise to conquer this increasing public health risk. It consists of entomologist Brenner, an architect, two pediatricians, an epidemiologist, two medical anthropologists, an immunologist, an environmental engineer, and a major corporation that may market equipment to help make homes more insect-resistant.

For the first time, the problem will be viewed from every standpoint: By changing how our homes are built, helping us live a lifestyle that doesn't encourage cockroaches to bunk with us, and—for those times these preventive measures don't totally do their job—by improving procedure in the allergist's office.

RICHARD NOWITZ

To develop test extracts specific to cockroach proteins, immunologist Rick Helm (left), medical anthropologist Kathleen Barnes (center), and entomologist Richard Brenner examine potential allergenic proteins isolated during acrylamide gel electrophoresis. (K-3577-1)

RICHARD NOWITZ



Volunteer Janette Breeding inhales small quantities of cockroach allergen as part of a pulmonary function test. (K-3578-13)

Attic Study

Air Vent, Inc., of Peoria, Illinois, set up for Brenner at the Gainesville lab an attic building. Its sole purpose: to study how cockroaches behave under different conditions in an attic environment [See *Agricultural Research*, September 1989].

Throughout the attic, Brenner and technician David Milne placed sensors that monitor temperature, moisture, and airflow, as well as cockroach movement in the attic.

The airflow sensors they needed had to be very small, inexpensive, and capable of measuring even slight air movement—down to 1 meter per minute.

William B. Rose, architect and associate professor at the Small Homes Council-Building Research Council at the University of Illinois at Urbana-Champaign, found sensors that would fit the bill. He and Brenner worked together to get the perfect calibration for the cockroach attics.

In his own research at the Council, Rose has eight attics, each constructed differently. (One, for example, has vaulted cathedral ceilings, common in many new homes these days.) He is finding out how each type of construction affects moisture, temperature, and airflow. From that data, Brenner can extrapolate whether each type encourages or discourages the survival of cockroaches—not just in the attic but in the rest of the home as well.

Building New Homes

"In the long run, we could make recommendations to Bill Rose, who could in turn make recommendations to the building industry, as to what type of home will prevent the buildup of cockroach populations and, therefore, cockroach allergen," Brenner says.

"Concerning cockroaches, architects and contractors never really gave much thought to the problems that may result from their construction practices. We need to come up with some solutions that will still allow us to build energy-efficient homes, so that's why we have to put our ideas together."

In one attic study, the scientists put ridge vents in one half of the divided attic to create air flow and left the other half unventilated. Each side had similar numbers of cockroaches when the study began. Within 2 weeks, most of the cockroaches had moved to the unventilated side.

"Cockroaches don't like airflow," Brenner says. "It's very drying to them. It may also be an evolutionary mechanism. A puff of air often meant a predator was nearby, so air tends to repel many organisms."

Brenner now suggests that builders might incorporate some type of airflow in those areas where cockroaches tend to aggregate: attics and wall voids. Those areas include underneath the baseboard or underneath cabinets. That way, they may be less likely to remain or survive in the home.

Even the type of nails used to build a house may affect whether or not cockroaches like living there. It has been well established that cockroaches prefer very narrow gaps as living space. Since, as architect Rose points out, the wood that frames a house ultimately shrinks, a house built without gaps between the wood initially will eventually provide perfect cockroach-sized gaps—if, that is, the nails are seemingly the "perfect" size to start with.

Rose says, "The recommendation would be to use the shortest nail necessary for fastening strength, because the longer the nail, the bigger the gap." He also says that if the wood is as dry as it is technically supposed to be, at 19 percent water, the shrinkage—and therefore the gaps—would be minimized.

Further, since research has proven that cockroaches survive best in a moist environment, Rose would, in the long run, like to promote the development of equipment that would remove moisture from a home without removing any of the heat (in the winter) or cool air (in hotter months).

In addition, ARS has signed a technology transfer agreement with Air Vent to impregnate insulation with cockroach repellants developed and patented by ARS. The insulation

RICHARD NOWITZ

Biological technician David Milne examines a filter containing allergens from an enclosed German cockroach colony. (K-3451-1)

may be marketed by Air Vent's parent company, CertainTeed, of Valley Forge, Pennsylvania. "These cockroaches will stay out under bright lights without food and water and starve to death before they'll go into a surface treated with these materials," Brenner says. He says that the team views this solution as one of the major components to building more insect-resistant homes.

Air Vent is sending insulation to Brenner, who will impregnate it with repellants. After running preliminary tests on the impregnated insulation, Brenner will test it in homes with serious infestations in Florida. "We'll rip out the insulation that's there and replace it with this," he says. That will bring the technology one step closer to homebuilders.

Treating Older Homes

When Brenner searched through scientific literature on cockroaches, he learned that some cockroach proteins—the culprits in causing allergy— persist for many years. "A home with no current cockroach problem could harbor allergy-producing cockroach parts from decades past," he says.

So the team is trying to work on a way to seal off and sequester the allergens in a home. Brenner will continue his attic work to learn exactly where the allergenic parts of the cockroach tend to accumulate.

. . . And for All Homes

The literature shows that some cockroach proteins are virtually indestructible—even boiling them for hours can't destroy their allergenicity. So Brenner envisions developing a technology to somehow destroy or denature the proteins.

Another possibility: develop some type of filtration system that would remove the allergens from the air. Gene Feigley, environmental engineer with the University of South Carolina, may collaborate on this research. Working with Brenner, his goal would be to see if some type of system could effectively remove the allergenic material.

RICHARD NOWITZ

Entomologist Richard Brenner preparing cockroaches for immunological assay. Roaches have 8-13 proteins that can cause allergic reactions in humans. (K-3453-6)

In the Allergist's Office

According to Rick Helm, immunologist at Children's Hospital in Little Rock, Arkansas, a suspected victim of cockroach allergy would traditionally be injected with ground-up cockroaches extracted and purified in a sterile saline solution. If results were positive for sensitivity, immunotherapy would begin. That would mean regular injections of—once again—ground-up, sterilized cockroaches.

But of the more than 50 identifiable cockroach proteins, only 10 to 15 actually cause a reaction in sensitive people, he says. So if a person is allergic to just 3 or 4 of those 10 to 15, they are being needlessly and repeatedly exposed to the others through immunotherapy. Allergists could be inadvertently inducing a sensitivity to the other proteins, Helm says.

So Brenner reared thousands of cockroaches and separated the parts that could be producing allergenic proteins—hemolymph (blood), exoskeleton (shell), digestive enzymes, and feces. He supplied them to Helm, who purified and separated the parts into the various proteins. Currently, Helm is working with pediatric allergists Larry Williams, M.D., and Wesley Burks, M.D., also of the University of Arkansas, to test cockroach-sensitive volunteers with these proteins. The redoubtable volunteers inhale a purified mist of each cockroach protein. The doctors record the immediate effects and carefully watch the patients for their reactions to these tests for 8 hours afterwards.

"This way we can home in on precisely which of the many proteins may be causing the problem in an allergic patient," Helm says.

The Entomologist's Viewpoint

"This work will also help us as we begin to look at new technologies for insect control," Brenner says. For example, many cockroach controls alter hormone production in the insect. This could in turn inadvertently increase the production of some proteins. "We don't want to be devising a hot new strategy that actually increases the amount of allergens."

Secondly, Brenner will need to know specifically which proteins provoke a response so that he can try to develop ways to deactivate the allergenicity of these proteins.

Members of the research team talk of a Utopia—a world where homes are built to be insect-resistant, where people's lifestyles don't accommodate a cockroach's lifestyle, and—when these preventive measures don't work—where allergists diagnose and treat only very specific allergies. Thanks to the team, we may eventually revert back to the days when talk of sniffly noses brought talk of just pollen, grasses, and mold.—By **Jessica Morrison Silva,** ARS.

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Profiles in Forage

At his Temple, Texas, greenhouse, plant geneticist Paul Voigt inspects hybrid crosses of weeping lovegrass. (K-3625-1) DAVID NANCE

> ***"Much of the beef produced in this country comes from cattle eating forage"***
>
> *Paul W. Voigt*

For most people, grass is simply something to be battled with a lawnmower on summer weekends. But for a group of researchers at Temple, Texas, grass represents a scientific treasure hunt.

The work of the Forage Improvement team at ARS' Grassland, Soil, and Water Research Laboratory often takes them down scientific byways that the average consumer might have trouble following. But the ultimate results are easy to understand: more abundant, more economical steaks, burgers, and shishkabobs on the grill.

"Much of the beef produced in this country comes from cattle eating forage," notes Paul W. Voigt, research leader for the unit. So developing better forage definitely has an impact for consumers."

The forage researchers tackle a variety of problems—finding grasses that can take hold and hang on in a less-than-hospitable environment; finding grasses that provide the most nutrition for cattle; and overcoming seed shattering— "when the seed falls off the plant before you can harvest it," Voigt explains.

One important offender in the last category is a forage called kleingrass. Kleingrass has proven its worth by surviving in areas with as little as 15 inches of water per year, and it now grows over many acres in Texas cattle country.

"But kleingrass has very bad seed shattering," says Voigt. "One of our geneticists estimates only 10 percent of the seed produced by kleingrass is actually harvested. The seed falls off almost as fast as it ripens."

In attempts to avoid this loss of harvest, grass seed producers may harvest kleingrass seed too early, gathering immature seed that won't produce many grass seedlings when it's planted.

ARS scientists have been looking for a better option, and they may have found it, according to Voigt. "We're working on a line of klein-

grass that retains about twice as much of its seed by 49 days after flowering as Selection 75, the standard cultivar being planted," he says.

This line, collected in South Africa in 1976, is being evaluated to see whether it has other desirable characteristics, such as adequate productivity.

It may be another 4 years before it's decided whether to release seed from this grass to producers. But Voigt says it's already made forage history: "To my knowledge, this is the first report of significant resistance to seed shattering in the entire species."

A forage with the picturesque name weeping lovegrass fills an important niche in grazing programs by remaining green well into winter and resuming growth earlier in the spring than most of the warm-season forages.

But weeping lovegrass is relatively low in quality and digestibility and requires intensive management for good animal performance, including scheduling grazing while the grass is young and fresh.

Voigt and his colleagues have searched for weeping lovegrass that, in addition to its characteristic ease of establishment and ability to survive, offers better digestibility. So far, they've found several promising candidates.

"We have about 50 strains we're working with," he says. "We've made crosses, and we're checking those hybrids for productivity, digestibility, and winter hardiness. But it could be another 10 years before we see weeping lovegrass with the characteristics we want."

While forage research is usually a long and winding road, at least one finding at the Temple lab could keep scientists from wasting time on a dead-end approach.

"There's been considerable work that shows if you select grasses for increased size of seed, you can get a more vigorous seedling," says Voigt. "But we've found that despite the larger seed, the adventitious roots don't develop any earlier. These are the roots that the seedling really needs to survive.

"We also know that kleingrass and another lovegrass called wilman have seeds of about the same size. But wilman lovegrass establishes much more easily and has a much more vigorous seedling.

"We found wilman lovegrass uses its seed reserves faster and has a higher respiration rate. This suggested we should be able to select for a more vigorous seedling without having to alter seed size. In fact, we have been able to do that. Now we need to speed up adventitious root development."

These hard-won answers will be of interest primarily to the livestock producer, but the benefits reach well beyond the farm gates.

"If we can increase the quality of forages, the cattle can gain more on grass than they otherwise would," Voigt says. "This means we can produce more beef without having more production costs."—By **Sandy Miller Hays**, ARS.

Paul W. Voigt is in USDA-ARS Forage Improvement Research, Grassland, Soil, and Water Research Laboratory, Temple, TX 76502 (817) 770-6521. ◆

DAVID NANCE

While kleingrass produces abundant seed, much of it shatters before it can be harvested. (K-3626-18)

"It could be another 10 years before we see weeping lovegrass with the characteristics we want."

Paul W. Voigt

The Rice Stuff *... It's all in the family*

Rice had not yet reached its quarter-century mark on eastern Arkansas' Grand Prairie, but already there was big trouble.

It was the mid-1920's, and Henry Daniel Dilday, a prominent rice farmer at Stuttgart, Arkansas, thought he knew how to best fight stem rot, a disease that was virtually destroying the rice crop. Individual research by the more progressive farmers simply wasn't enough; a unified effort was required.

So Dilday, with his son Henry Homer and a few others, went calling on neighboring farmers at night, attempting to raise the money to buy 160 acres. The land would be donated to the University of Arkansas Agricultural Experiment Station for use in rice research, hopefully to yield a solution to stem rot.

The University got its land in 1927, dubbing the Stuttgart facility the Rice Branch Experiment Station. But H.D. Dilday didn't just walk away satisfied. When the public came to look in on the facility for the first time on April 13, 1932, H.D. Dilday was on the three-man welcoming committee.

And when area farmers began donating varieties for the station's rice germplasm collection, he supplied two of the first three donations, Supreme Blue Rose and Early Prolific. Crossbreeding of various rices from the germplasm collection he helped establish eventually led to the development of rice cultivars tolerant of his old nemesis, stem rot.

When the Depression hit, even the prosperous Dildays were forced to move on, relocating from Stuttgart to Tuckerman in northeast Arkansas.

But the Stuttgart facility, renamed the Rice Research and Extension Center, thrived. So did its rice germplasm collection, which in 1930 came under the direction of Roy Adair, an agronomist with what later became USDA's Agricultural Research Service.

The rice germplasm collection at Stuttgart was eventually incorporated into the USDA-ARS National Small Grains Collection housed since August 1988 at Aberdeen, Idaho.

The rice portion of the Small Grains Collection has had only two overseers at Stuttgart since Adair: Ted H. Johnston from the 1950's to 1982, and since 1982, Robert Henry Dilday—the son of H.D. Dilday's son, Henry Homer.

Bob Dilday didn't plan to carry on his grandfather's interest in research. He'd always wanted to farm.

"My parents kept after me to go to college, so I said okay, I'd go, but only for 4 years, then I was coming back to the family farm," Dilday recalls. "But while I was still in high school, our place at Tuckerman was sold, so there wasn't any farm to go back to."

Dilday decided that the next best thing to managing the family farm would be a career in agricultural research. After earning bachelor's and master's degrees in agronomy at the University of Arkansas and a Ph.D. in plant breeding and genetics at Texas A&M University, he went to work for ARS in 1971 as a cotton geneticist at Brownsville, Texas. He

RICHARD NOWITZ

Research geneticist Robert Henry Dilday (background)with Henry Homer Dilday who is his father, a retired rice farmer, and grandfather Henry Daniel Dilday (photo), represent three generations of rice germplasm enthusiasts in Arkansas that covers about 70 years. H.D. Dilday gave the first rice germplasm accession to the Rice Branch Experiment Station near Stuttgart, Arkansas, in 1927. H.H. Dilday continued this work, and R.H. Dilday presently coordinates the USDA/ARS rice germplasm collection evaluation program. (K-3601-5)

stayed at Brownsville until taking the job at Stuttgart. Not only would H.D. Dilday be gratified by his descendant's work—he'd undoubtedly be impressed, too.

"There are now about 20,000 accessions in the USDA-ARS rice germplasm collection, with germplasm from 99 different countries," Dilday explains.

"I evaluate 4,000 to 5,000 accessions at a time for information such as days to maturity, plant height, disease and herbicide resistance, and allelopathy—the ability to repel weeds naturally. Last year, we looked at about 22,000 entries in evaluation tests.

"We need to do these evaluations because, although we have a large collection, we really do not know what's there in terms of useful characteristics."

Supplies of rice seed are kept at Aberdeen, where scientists from around the world can obtain samples for research purposes. When the Aberdeen supply of a particular rice accession drops below 50 grams, Dilday grows more.

"All of the small grains in the collection except rice can be grown at Aberdeen," he says. "But the seed increase and evaluation for rice must be conducted here at Stuttgart."

Samples of any new rice accession developed in the United States or imported from anywhere are donated to the collection. But not all are accepted, Dilday notes: "It has to have some unique property. We don't want a lot of sister lines in the collection."

Dilday's evaluations are vital; the massive U.S. rice industry actually rests on a fairly narrow—and possibly vulnerable—germplasm base.

"If you look at the pedigrees of the 140 different rice varieties that have been grown commercially in the United States, all can be traced to just 22 plant introductions in Arkansas, Louisiana, Mississippi, and Texas, and 23 in California," he says.

The genetic base of the entire southern breeding programs can be traced to 13 parental accessions in Arkansas, 12 in Texas, and 16 in Louisiana. Furthermore, 10 of the parental accessions in the Texas and Arkansas breeding programs are identical, as are eight of the parental accessions in the Arkansas and Louisiana programs.

"This potentially leaves us wide open to some major disease, insect, or environmental problem," says Dilday. "I think it would be a big mistake if the diversity that we already have on hand in our collection wasn't evaluated and used to develop new varieties."

For all its serious consequences, the job is more than just business to Dilday. "Sometimes, I still kind of pinch myself to see if I'm just dreaming that here I am, carrying on what my dad and granddad helped start," he says. "This is something they and other progressive farmers around Stuttgart saw a need for 60 years ago."—By **Sandy Miller Hays**, ARS.

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RICHARD NOWITZ

Plant geneticist Robert Dilday inspects rice seeds from a cross between exotic germplasm possessing allelopathic properties to weed species and an agronomically acceptable cultivar. (K-3602-16)

Emasculation of the rice flower is the first step in transferring desirable genes from exotic germ-plasm into commercial cultivars—a process known as hybridization. (K-3602-11)

About 10,000 of the rice accessions in the USDA/ARS rice germplasm collection are maintained in short-term storage at the Stuttgart, Arkansas, laboratory as part of the national rice germplasm evaluation program. (K-3603-10)

AGNOTES

Sweeter Onions Are More Bee-Guiling

Honey bees shy away from the onions of the Southwest, and that's a problem for producers.

Low seed yields from onions grown there push up the price of onions at the supermarket. Arizona and California growers could produce far more seed if honey bees were more willing to cuddle up.

ARS entomologist James R. Hagler studied the extent of the insects' onion aversion. "When we moved hives into onion fields," he says, "the bees flew out, straight up into the air, about 10 feet above the crop, and flew to blooming mesquite shrubs up to 200 yards distant, rather than gather the onion nectar or pollen."

When honey bees and other insects fail to pollinate, only onion flowers that receive airborne pollen will produce seed. Such haphazard pollination severely cuts yield in Arizona and California. Depending on weather and bee activity, some onion seed yields have been reduced by up to 80 percent.

About $10 billion worth of U.S. crops annually, ranging from fruit to forage, rely on honey bees for pollination. Bees inadvertently move pollen from flower to flower while they collect pollen and nectar that serves as food for bees. In the hive, bees convert the nectar collected into honey.

Hagler, who is based at the Carl Hayden Honey Bee Research Center, Tucson, Arizona, studied six commercial onion varieties and identified what bees dislike in onion nectar—high potassium and low sugar content, especially sucrose. He also found enough variability between the varieties to convince him that geneticists can breed more attractiveness into onion plants.

Wild onions could also be a possible genetic pool to draw on for improved varieties. The bee's intense dislike for onion nectar is unique to commercial onions; they have no trouble with nectar from wild onions.

It's not clear why the problem is more acute in California and Arizona than in the Pacific Northwest, another major onion seed-producing area. Bees there don't usually have a problem pollinating the crop, which is grown during the summer.

Sweetening the nectar in onions would up the year-round efficiency of U.S. onion seed production; the crop is grown in the winter and spring in the Southwest.

Hagler is publishing his findings to alert onion breeders to the need for nectar attractiveness in future varieties.—By **Dennis Senft,** ARS.

James R. Hagler is at the USDA-ARS Honey Bee and Biological Control of Insects Unit, Carl Hayden Bee Research Center, 2000 East Allen Road, Tucson, AZ 85719 (602) 670-6220. ◆

New Tests Pinpoint Soy Compounds

Two natural compounds in soybean, known as trypsin inhibitors, can sabotage your body's ability to receive the full benefits of soy's high-quality protein.

Now, producers of soy-based diet shakes or infant formulas, soy flour, soy sauce, and related foods can use two new assays to find out if any active trypsin inhibitors remain in their products after conventional processing.

The tests, developed by David L. Brandon, Anne H. Bates, and Mendel Friedman with ARS' Food Safety Unit in Albany, California, give more accurate results than other techniques for detecting the Kunitz or Bowman-Birk inhibitors.

Unlike earlier tests, each assay can accurately distinguish one inhibitory compound from the other, and can detect them even in very small amounts, Brandon says.

Both tests rely on proteins called monoclonal antibodies to seek out and bind to the inhibitors. Brandon and colleagues produced the new monoclonal antibodies initially in laboratory mice, then in cells kept alive in the laboratory.

In addition to soy processors, Brandon notes that other groups might be interested in the new assays. Plant breeders who want to develop soybean varieties naturally low in both inhibitors could use the tests to check new strains.

Researchers who are trying to sort out conflicting claims about the effects of the inhibitors should find the antibodies useful. That group may include scientists who are following up on studies, first reported in 1983, that showed that the Bowman-Birk inhibitors had cancer-fighting effects in laboratory animals.—By **Marcia Wood,** ARS.

For technical information about these patents contact David L. Brandon, USDA-ARS, Food Safety Research Unit, Western Regional Research Center, 800 Buchanan St., Albany, CA 94710 (415) 559-5783, Patent Serial No. 07/101,918, "Monoclonal Antibodies to Soybean Kunitz Trypsin Inhibitor and Immunoassay Methods" and Patent Serial No. 07/246,842, "High Affinity Monoclonal Antibodies to Bowman-Birk Inhibitor and Immunoassay Methods." ◆

Computer Guides Cattle Stocking Rate

Although many seasoned ranchers are good at matching cattle herd size to their grass supply, it's now possible for even inexperienced livestock producers to match the number of cattle on their rangeland to the available forage.

This match is possible with a computer program called SMART—Simple Model to Assess Range Technology—which helps ensure that land is not overgrazed and that ranchers get maximum beef production at the lowest cost.

"The rancher inputs the stocking rate, initial weight of steers, total annual forage production, and seasonal pattern of forage quality. Then SMART prints out forage supply and gains for each day and the cumulative totals for the grazing season," says ARS range scientist Richard H. Hart at the High Plains Grasslands Research Station, Cheyenne, Wyoming.

By running the program on a desktop computer, the rancher can try out a number of stocking rates and forage types, evaluate the results, and decide which alternative to adopt.

In the previous century and during the early part of this one, some ranchers would stock the same number of cattle year after year—say one cow and her calf per 20 acres of rangeland. That practice was sometimes disastrous both to the environment and to cattle.

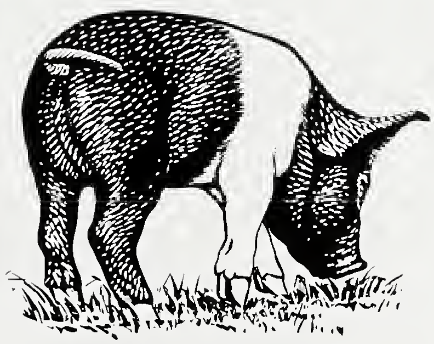
"Extended droughts such as those of the 1880's or 1930's caused cattle to devour every blade of grass on the range. Even when the cattle survived, this ranching practice cut into profits," says Hart.

Modern-day ranchers are more flexible; they trim herd size when prices fall or when grasses fail to provide enough nutrition. Hart says the computer model will encourage better management and more stable income.

Growth rates and quality of plants in many range ecosystems can be built into the model. The present version is designed for yearling cattle, but a version for cow-calf operations is also being developed.

There is no charge for the program, which is written in the BASIC computer language. To obtain a copy, send Hart a blank 5.25-inch, double-density diskette.—By **Dennis Senft,** ARS.

Richard H. Hart is at the USDA-ARS High Plains Grasslands Research Station, 8408 Hildreth Rd., Cheyenne, WY 82009 (307) 772-2433. ◆



Spotting Swine Dysentery

Some little pigs don't make it to market because of swine dysentery. This debilitating disease, also known as black or bloody scours, causes severe intestinal lesions and diarrhea. It usually occurs in pigs 8 to 14 weeks old, although older pigs are sometimes affected.

Pigs infected with swine dysentery become dehydrated and don't gain weight—and, to a producer, weight is money. Although it's not usually a killer, the disease causes serious economic losses.

The disease is caused by the spirochete bacterium, *Treponema hyodysenteriae (T. hyo).* Animals that recover from the disease may still harbor the spirochete without showing disease symptoms.

"Quick diagnosis can be critical to control of swine dysentery," says Neil S. Jensen, ARS microbiologist at the National Animal Disease Center in Ames, Iowa. Current laboratory diagnostic tests rely on culturing fecal samples, a process that can take from 4 to 6 days.

"But in that time, the quick-spreading disease could render a pig operation nonproductive," says Jensen. Besides being slow, culturing techniques are not always able to distinguish *T. hyo* from other non-pathogenic spirochetes, such as *T. innocens* and *T. succinifaciens,* which may also be found in the pig's intestine.

Jensen and coworker Thad B. Stanton developed a DNA probe that can detect *T. hyo* in pig fecal samples. With it, an accurate diagnosis of swine dysentery can be made in 1 to 2 days.

The probe is a single strand of DNA that binds to the ribosomal RNA of *T. hyo.* The probe contains a radioactive tag making its binding to the target RNA detectable by exposure to x-ray film.

A region of the ribosomal RNA of the disease-causing spirochete has a sequence, "like a signature—unique to that organism," says Jensen. The probe binds to that signature sequence and, in doing so, unmistakably identifies the spirochete.

The pork industry has expressed interest in ridding the United States of swine dysentery. This diagnostic test could help convert such concern into a workable eradication program.—By **Linda Cooke,** ARS.

Neil S. Jensen and Thad B. Stanton are at the National Animal Disease Center, P.O. Box 70, Ames, IA 50010 (515) 239-8288. ◆

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